Substitute specification

Manufacturing Method and Apparatus of Phase Shift Mask Blank

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5   (now U.S. 6,783,634 issued August 31, 2004. This application claims the Paris convention priority of Japanese patent application 2000-277354 filed on September 12, 2000, the entire disclosure of which is incorporated herein by · reference.
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BACKGROUND OF THE INVENTION

i) Field of the Invention

The present invention relates to a manufacturing method and apparatus of a phase shift mask blank which is
15   suitable particularly for ArF or F_2 excimer laser.

ii) Description of the Related Art

In recent years, it has become clear that high resolution and depth of focus are two important properties required for photolithography but are in a contradictory
20   relation with each other, and that a practical resolution cannot be enhanced using only a short wavelength laser and an exposure apparatus with a lens having a high numerical aperture ("NA"). (Monthly Semiconductor World 1990.12, Applied Physics Vol. 60, November, 1991, and the like).
25   In such a situation, phase shift lithography has been noted as the next-generation photolithography technique, and partially brought to practical use. Phase shift

lithography is a method for enhancing the resolution of photolithography by changing only a mask without changing an optical system. When a phase difference is applied between exposure lights transmitted through the photo mask, mutual

5   interference of the transmitted lights can be utilized to rapidly enhance the resolution.

The phase shift mask is a mask which uses light strength information together with phase information. Various types of masks are known such as Levenson type,

10   auxiliary pattern type, and self-matching type (edge emphasizing type). These phase shift masks have a complicated structure and require a high degree of manufacturing technique as compared with the conventional photo mask which uses only light strength information.

15   In recent years, a so-called halftone type phase shift mask has been developed as one of the phase shift masks.

In a halftone phase shift mask, a light semi-transmission section has two functions: a shield function of

20   substantially shielding the exposure light and a phase shift function of shifting (usually reversing) a light phase. Therefore, it is unnecessary to separately form a shield film pattern and a phase shift film pattern. This type of phase shift mask is structurally simple and easy to

25   manufacture.

In a halftone phase shift mask, a mask pattern is processed by a dry etching process. However, when providing

the shield function and phase shift function by separate layers, a high degree of control is necessary for both the layer having the shield function and the layer having the phase shift function in order to obtain a satisfactory

5   pattern shape. On the other hand, when creating a single-layer light semi-transmission portion having both the shield function and the phase shift function, a single etching process can be used. Therefore, the manufacturing process of such a mask can be simplified, and a satisfactory pattern

10   shape can easily be obtained.

For the halftone phase shift mask, as shown in FIG. 10, a mask pattern formed on a transparent substrate 100 is constituted of a light transmission portion (transparent substrate exposed portion) 200 for transmitting a light

15   which is strong enough to substantially contribute to exposure and a light semi-transmission portion (shield and phase shifter portion) 300 for transmitting a light which is not strong enough to substantially contribute to the exposure (FIG. 10A). Additionally, the phase of the light

20   transmitted through the light semi-transmission portion is shifted to a substantially reversed relation with respect to the phase of the light transmitted through the light transmission portion (FIG. 10B). The oppositely-phased lights transmitted in the vicinity of a boundary between the

25   light semi-transmission portion and the light transmission portion cancel each other on account of diffraction phenomenon. Thereby, light strength in the boundary is

substantially set to zero and, in contrast, resolution in the vicinity of the boundary is enhanced (FIG. 10C).

Additionally, the light semi-transmission portion or film (phase shift layer) in the halftone phase shift mask or blank needs to indicate a required optimum value with respect to both transmittance and phase shift amount. For example, (1) the transmittance in exposure wavelength of i-ray, KrF excimer laser, ArF excimer laser, or the like can be adjusted in a range of 3 to 20%, (2) a phase angle can be adjusted usually to a value in the vicinity of 180° in the exposure wavelength, and (3) the transmittance needs to be usually testable in a range of 65% or less in test wavelengths such as 257 nm, 266 nm, 364 nm, and 488 nm.

However, by shortening the wavelength of the laser for use in the exposure to ArF excimer laser (193 nm) from i-ray (365 nm) and KrF excimer laser (248 nm), the following problem is generated in the conventional halftone phase shift mask and the manufacturing method of the mask.

That is, in mass production of the phase shift mask blanks, when there are dispersions of the phase angle and transmittance among the blanks or in the plane, the yield is bad. Particularly in mask blanks for the short wavelength of ArF or F_2 excimer lasers, the dispersions of the phase angle and transmittance among the blanks and in the plane in conventional mask blanks for i-ray and KrF excimer laser are large, and the yield is bad. Therefore, the resulting mask blanks cannot be used.

SUMMARY OF THE INVENTION

The present invention has been developed under the aforementioned background, and a first object thereof is to provide a manufacturing method of a phase shift mask blank in which dispersions of a phase angle and transmittance among blanks can be reduced as much as possible and the yield is satisfactory.

Moreover, a second object is to provide a manufacturing method of a phase shift mask blank in which the dispersions of the phase angle and transmittance in a plane of the blanks can be reduced as much as possible and the yield is satisfactory.

Furthermore, a third object is to provide a manufacturing apparatus of a phase shift mask blank in which the dispersions of the phase angle and transmittance among the blanks can be reduced as much as possible and which can be manufactured with a satisfactory yield.

Additionally, a fourth object is to provide a manufacturing apparatus of a phase shift mask blank in which the dispersions of the phase angle and transmittance in the plane of the blanks can be reduced as much as possible and which can be manufactured with a satisfactory yield.

To achieve the aforementioned objects, the present invention has the following constitutions:

(Constitution 1) A method of continuously manufacturing a plurality of phase shift mask blanks each having at least a

phase shift film on a transparent substrate, the method comprising a step of:

using a sputtering method to continuously form the phase shift film on the transparent substrate,

5   wherein the dispersion of a phase angle of the phase shift film among the plurality of blanks is within $\pm 2°$.

(Constitution 2) A method of continuously manufacturing a plurality of halftone phase shift mask blanks each having at least a light semi-transmission film on a transparent

10   substrate, the method comprising a step of:

using a sputtering method to continuously form the light semi-transmission film on the transparent substrate,

wherein the dispersions of a phase angle and transmittance of the light semi-transmission film among the

15   plurality of halftone phase shift mask blanks are within $\pm 2°$ and $\pm 4\%$, respectively.

(Constitution 3) A method of continuously manufacturing a plurality of photo mask blanks each having at least a thin film for forming a pattern on a transparent substrate, the

20   method comprising a step of:

using a sputtering method to continuously form the thin film on the transparent substrate,

wherein the sputtering method includes the steps of: successively supplying a plurality of transparent

25   substrates into a sputtering chamber, forming the thin film for forming the pattern in the sputtering chamber, and discharging the transparent substrate with the film formed

thereon from the sputtering chamber; wherein the transparent substrates are supplied and discharged substantially at a constant interval in order to set a film formation time which is constant among the plurality of blanks, and

5   discarding at least the first five photo mask blanks obtained in the step.

(Constitution 4) The manufacturing method according to constitution 3 wherein the thin film for forming the pattern is a phase shift film, and the photo mask blank is a phase

10 shift mask blank.

(Constitution 5) The manufacturing method according to constitution 3 wherein the thin film for forming the pattern is a light semi-transmission phase shift film, and the photo mask blank is a halftone phase shift mask blank.

15 (Constitution 6) A manufacturing method of a photo mask blank having a thin film for forming at least a pattern on a transparent substrate, the method comprising the steps of:

         rotating the substrate; sputtering a target disposed opposite to a position whose center axis deviates from a

20 center axis of the substrate; and forming the thin film.

(Constitution 7) The manufacturing method according to constitution 6 wherein the target and the substrate are disposed so that opposite surfaces of the substrate and target form a predetermined angle therebetween.

25 (Constitution 8) The manufacturing method according to constitution 6 or 7 wherein the step of forming the film comprises a step of rotating the transparent substrate an

integral number of times between the start of film formation and the end of the film formation.

(Constitution 9) The manufacturing method according to any one of constitutions 6 to 8 wherein the thin film for forming the pattern is a phase shift film, and the photo mask blank is a phase shift mask blank.

(Constitution 10) The manufacturing method according to constitution 9 wherein a dispersion of a phase angle of the phase shift film in a plane is within ±2°.

(Constitution 11) The manufacturing method according to any one of constitutions 6 to 10 wherein the thin film for forming the pattern is a light semi-transmission phase shift film, and the photo mask blank is a halftone phase shift mask blank.

(Constitution 12) The manufacturing method according to constitution 11 wherein a dispersion of a phase angle of the light semi-transmission phase shift film in a plane is within ±2° and a dispersion of a transmittance in the plane is within ±4%.

(Constitution 13) The manufacturing method according to constitution 11 or 12 wherein the light semi-transmission phase shift film is formed by sputtering the target, which is formed of a metal and silicon, in an atmosphere containing nitrogen, such that the resulting content of nitrogen in the light semi-transmission phase shift film is larger than the content of silicon therein.

(Constitution 14) A photo mask manufactured by patterning

the thin film onto the photo mask blank according to any one of constitutions 1 to 13.

(Constitution 15) A pattern transfer method of using the photo mask according to constitution 14 to transfer a pattern.

(Constitution 16) A manufacturing apparatus of a photo mask blank, comprising at least: a load lock mechanism for introducing substrates one by one; a sputtering chamber for forming a film on a substrate; a load lock chamber; a substrate-conveying mechanism for introducing the substrates one by one to the sputtering chamber from the load lock chamber at a constant interval; and an unload lock mechanism for discharging the substrates one by one from the sputtering chamber.

(Constitution 17) A manufacturing apparatus of a photo mask blank, comprising: a substrate holder having a rotation mechanism; and a target disposed opposite to a position whose center axis deviates from a center axis of a substrate.

(Constitution 18) The manufacturing apparatus according to constitution 17 wherein the target and the substrate are disposed so that opposite surfaces of the substrate and target form a predetermined angle therebetween.

(Constitution 19) The manufacturing apparatus of the halftone phase shift mask blank according to any one of constitutions 16 to 18, comprising: means for detecting a rotation position of the substrate; and means for turning OFF the electric discharge (ending film formation) when the

substrate has completed an integral number of rotations after turning ON the electric discharge (starting the film formation), so as to allow the substrate to reach the same rotation angle position as the rotation angle position when the electric discharge was turned ON.

According to constitutions 1 and 2, the dispersion of the phase angle of the phase shift film among the phase shift mask blanks is within $\pm 2°$, or the dispersions of the phase angle and transmittance of the light semi-transmission film among the halftone phase shift mask blanks are within $\pm 2°$ and within $\pm 4\%$, respectively. Therefore, the phase shift masks for a short wavelength of ArF or F_2 excimer laser can be mass-produced for practical use. When this range is exceeded, it is difficult to mass-manufacture and practically use the phase shift mask for the short wavelength of ArF or F_2 excimer lasers.

Additionally, even in the present situation, masks for KrF excimer lasers can be practically used. However, smaller dispersions of the phase angle and transmittance of the light semi-transmission film among the mask blanks are preferable. Therefore, the invention according to constitutions 1 and 2 can also be applied to phase shift mask blanks for KrF excimer lasers.

According to constitutions 3 to 5, the dispersions of film properties (transmittance (OD), film thickness, and the like) among the blanks can be suppressed. It is particularly possible to realize the manufacture of a phase

shift mask in which the dispersion of the phase angle of the phase shift film among the phase shift mask blanks is within $\pm 2°$, or the dispersions of the phase angle and transmittance of the light semi-transmission film among the halftone phase

5   shift mask blanks are within $\pm 2°$ and within $\pm 4\%$, respectively.

According to constitutions 6 to 12, the dispersions of the film properties (transmittance (OD), film thickness, and the like) in the plane in the photo mask blank can be

10   suppressed. It is particularly possible to realize a phase shift mask blank in which the dispersion of the phase angle of the phase shift film in the plane of the phase shift mask blank is within $\pm 2°$, or the dispersions of the phase angle and transmittance of the light semi-transmission film in the

15   plane of the halftone phase shift mask blank are within $\pm 2°$ and within $\pm 4\%$, respectively. Therefore, a phase shift mask for the short wavelength of an ArF or F_2 excimer laser can be brought to practical use. When this range is exceeded, it is difficult to practically use the phase shift mask for the

20   short wavelength of an ArF or F_2 excimer laser.

Additionally, even in the present situation, the mask for a KrF excimer laser can be practically used. However, smaller dispersions of the phase angle and transmittance of the light semi-transmission film in the plane of the mask

25   blank are preferable. Therefore, the invention according to constitutions 6 and 12 can also be applied to the phase shift mask blank for a KrF excimer laser.

According to constitution 13, the dispersion of the phase angle can further be suppressed.

According to constitution 14, it is possible to obtain the photo mask in which the dispersion among the masks or in the mask plane is suppressed.

According to constitution 15, a superior patterning process can be realized.

According to the apparatus of constitutions 16 to 19, the dispersions of the film properties (transmittance (OD), film thickness, and the like) in the photo mask blank among the blanks or in the plane can be suppressed. It is particularly possible to realize the manufacture of a phase shift mask blank in which the dispersion of the phase angle of the phase shift film among the phase shift mask blanks or in the plane is within ±2°, or the dispersions of the phase angle and transmittance of the light semi-transmission film among the halftone phase shift mask blanks or in the plane are within ±2° and within ±4%, respectively.

The present invention will be described hereinafter in more detail.

As a result of research conducted in order to achieve the aforementioned objects, the following has been discovered:

In a halftone phase shift mask, it is functionally important to adjust the phase angle and transmittance of the light semi-transmission portion, so as to obtain the desired values. For an error range of the phase angle and

transmittance, fluctuation among blanks (dispersion among blanks), and in-blank distribution (in-plane dispersion) is required to be about ±2° and ±4%, respectively. Examples of factors which change the phase angle and transmittance

5   include: (1) the film formation procedure of the light semi-transmission film; (2) the characteristics of the sputtering apparatus used for forming the light semi-transmission film, and (3) the material of the light semi-transmission film.

     (1) The film formation procedure for forming the

10   light semi-transmission film will be described in detail.

     In the process of determining a film formation time of the light semi-transmission film for a sputtering step, when an interval between consecutive sputtering steps is set to be constant, fluctuations of the phase angle and

15   transmittance among blanks (dispersion among blanks) within ±2° and within ±4%, respectively, will result in enhanced reproducibility of effective blanks. In sputtering phenomenon, temperature and surface state of a target or a shield may be changed, and the degree of vacuum in a vacuum

20   tank may also be changed. In a conventional intermittent sputtering process in which the interval between the end of one sputtering step and the start of the next sputtering step is not constant, the state of the target or the shield changes every moment. However, in the present invention,

25   wherein: the interval between sputtering steps, the duration of each sputtering step, and surface condition are always set to be constant, the fluctuations of the phase angle and

transmittance are reduced after initially forming five to ten blanks. That is, when the light semi-transmission film is continuously formed at a constant interval, and the first five to ten blanks formed are discarded, it is possible to steadily manufacture halftone phase shift mask blanks having less fluctuations of the phase angle and transmittance. Concretely, it is possible to steadily manufacture halftone phase shift mask blanks in which the dispersions of the phase angle and transmittance among the blanks are within ±2° and within ±4%, respectively.

In order to realize this process, as shown in FIG. 1, a load lock mechanism, which can constantly hold a sputtering vacuum tank (sputtering chamber) in a high vacuum state, is needed. In such an apparatus, introduction of the substrate to the sputtering chamber from a load lock chamber is continuously performed at a constant interval. For this, a load lock mechanism for introducing the substrates one by one is needed. Additionally, the capacity of the load lock chamber needs to be designed such that the substrate is continuously introduced to the sputtering chamber from the load lock chamber at the constant interval.

In the conventional manufacturing apparatus of halftone phase shift mask blanks, about ten substrates are simultaneously set in the load lock chamber. In this system (or an in-line system), since the capacity of the load lock chamber is large, much time is required for setting the inside of the load lock chamber to a predetermined degree of

vacuum, and film formation is not performed in the sputtering chamber during this time. Therefore, when the film formation for one batch of substrates ends and the next cassette is set in the load lock chamber in order to perform

5   film formation, the substrates are not being continuously supplied to the sputtering chamber at a constant interval. In this case, when the substrates are not continuously introduced to the sputtering chamber at a constant interval, the film formation in the sputtering chamber is not

10   stabilized, the dispersions of the phase angle and transmittance among the blanks are large in the first five to ten blanks, and yield is disadvantageously bad.

In FIG. 1, a valve 12 for separating a load lock chamber 11 from the atmosphere, and a valve 14 for

15   separating the load lock chamber 11 from a sputtering chamber 13 are attached to the load lock chamber 11. The load lock chamber 11 has a valve system in which the substrate can continuously be introduced to the sputtering chamber at the constant interval as described above. The

20   load lock chamber is also designed to have a predetermined capacity. The sputtering chamber 13 has a function equivalent to a function of the vacuum tank in which sputtering is performed as described later and shown in FIG. 2. When the substrate is introduced to the sputtering

25   chamber 13 by a robot arm, a conveying chamber 15 may be disposed between the sputtering chamber 13 and the load lock chamber 11. For a robot arm 19, when an arm 19a

opens/closes in a direction A, a hand 19b can move in a
direction B. Moreover, the robot arm 19 can rotate in a
direction C. The robot arm 19 is also designed to be movable
in a vertical direction with respect to a sheet surface.

5 Furthermore, in order to enhance the efficiency of film
formation, an unload lock chamber 16 having a design similar
to that of the load lock chamber 11 may be added. An example
of the process for forming the light semi-transmission film
on the transparent substrate will be described with

10 reference to FIG. 1.

1) After the valve 14 is closed, the inside of the
load lock chamber 11 is set to atmospheric pressure through
venting.

2) The valve 12 is opened and one transparent

15 substrate is introduced into the load lock chamber 11.

3) The valve 12 is closed and the load lock chamber
11 is evacuated.

4) After the load lock chamber 11 reaches a
predetermined degree of vacuum, the valve 14 is opened and

20 the transparent substrate is moved to the sputtering chamber
13.

5) An assembly described later and shown in FIG. 2
is used to form the light semi-transmission film in the
sputtering chamber 13.

25 6) After the end of formation of the light semi-
transmission film, a valve 17 is opened and the substrate is
moved to the unload lock chamber 16. In this case, it is

necessary to depressurize the unload lock chamber 16 to the predetermined degree of vacuum.

7) After the valve 17 is closed, the unload lock chamber is brought to atmospheric pressure through venting.

8) A valve 18 is opened and the substrate is removed.

From the time when the light semi-transmission film is formed in the sputtering chamber 13, until the substrate is moved to the unload lock chamber 16 from the sputtering chamber 13, steps 1) to 4) are ended, and the next substrate is allowed to be on standby in the load lock chamber 11. When the previous film formation ends, and the substrate is moved to the unload lock chamber 16 from the sputtering chamber 13, the transparent substrate having been on standby is moved to the sputtering chamber 13, and the light semi-transmission film is successively formed. By this process, it is possible to successively (continuously) form the light semi-transmission film at the constant interval excluding a time of maintenance of the apparatus.

(2) The characteristics of the sputtering apparatus for forming the light semi-transmission film will next be described in detail. Since gas pressure during the sputtering for forming the light semi-transmission film, output of a sputtering DC power supply, and sputtering time directly influence the transmittance and phase angle, precision of a gas flow rate controller, DC power supply or another apparatus needs to be enhanced. It is also

necessary to enhance the precision of a set signal emitted from the controller. Since the gas pressure during the sputtering is also influenced by exhaust conductance of the apparatus, a mechanism able to accurately determine an open degree of an exhaust port valve and a position of the shield is also necessary. A suitable control mechanism will be described later.

Moreover, for a film containing silicon nitride, moisture generated from an inner wall of the vacuum tank, or the presence of another gas, largely influences an optical property of the film. It is therefore necessary to include a pump which can sufficiently evacuate the vacuum tank, and a mechanism which can bake the inner wall of the vacuum tank. The degree of vacuum in the vacuum tank needs to be about 2×10^{-5} pa or less at a film formation speed of 10 nm/min, and 1×10^{-5} pa or less at a film formation speed of 5 nm/min.

Furthermore, in order to suppress the distributions of the phase angle and transmittance in the blanks (dispersions in the plane) to within $\pm 2°$ and $\pm 4\%$, respectively, the transparent substrate needs to be rotated during the film formation. It is further necessary to rotate the transparent substrate an integral number of times between the start and the end of the film formation step. To this end, for example, the rotation angle position of the substrate when the electric discharge is turned ON (start of film formation) is detected by a sensor. Furthermore, as per another function of this sensor, after the substrate

completes an integral number of rotations and reaches the
same rotation angle position as at the time that the
electric discharge was turned ON, the electric discharge is
turned OFF (film formation is ended). Such a sensor

5   mechanism needs to be included.

The distributions of the phase angle and
transmittance in the plane also change with a positional
relation between the substrate and the target. The
positional relation between the target and the substrate

10   will be described with reference to FIG. 8.

An offset distance (distance between a center axis
of the substrate and a straight line passed through a center
of the target and extended in parallel to the center axis of
the substrate) is adjusted by an area in which the

15   distributions of the phase angle and transmittance are to be
secured. Generally in a large area in which the
distributions are to be secured, a large offset distance is
necessary. In order to realize the phase angle distribution
within ±2° and transmittance distribution within ±4% in a 152

20   mm square substrate as in the present embodiment, the offset
distance needs to be in a range of about 200 mm to 350 mm,
and a preferable offset distance is in a range of 240 mm to
280 mm.

An optimum range of a vertical distance between the

25   target and the substrate (T/S) changes with the offset
distance. However, in order to realize the phase angle
distribution within ±2° and transmittance distribution

within ±4% in the 152 mm square substrate, the vertical

distance between the target and the substrate (T/S) needs to

be about 200 mm to 380 mm, and preferably T/S is in a range

of 210 mm to 300 mm.

5   A target inclination angle influences the film

formation speed. In order to obtain a high film formation

speed, an appropriate target inclination angle is in a range

of 0° to 45°, and a preferable target inclination angle is

in a range of 10° to 30°.

10   FIG. 9 shows upper and lower limits of T/S with

which a phase angle distribution within ±2° and transmittance

distribution within ±4% can be realized in the 152 mm square

substrate for a particular offset distance.

        (3) The influence of the material of the light

15   semi-transmission film on the phase angle and transmittance

will next be described in detail. The phase angle and

transmittance of the light semi-transmission film change

with the film formation speed and degree of nitriding. The

film formation speed and degree of nitriding are influenced

20   by a nitrogen partial pressure during sputtering. However,

when the light semi-transmission film is completely nitrided,

the influence of the nitrogen partial pressure during

sputtering is reduced. In a nitrided metal silicide film, a

flow rate of nitrogen introduced during sputtering is

25   adjusted so that the content of nitrogen measured by ESCA is

larger than that of silicon. This can reduce the influence

of a fluctuation of nitrogen partial pressure on the optical

property. With this method, the distributions of the phase

angle and transmittance in the plane can also be reduced.

Additionally, when oxygen is added together with nitrogen

during sputtering, the phase angle and transmittance are

5   largely influenced by a fluctuation of the flow rate of

oxygen. However, at least the influence of flow rate

fluctuation of nitrogen can be reduced in the aforementioned

method.

       Additionally, the photo mask blanks of the present

10   invention may include a shield film (chromium, a chromium

compound containing oxygen, nitrogen, carbon, and the like in

chromium, another chromium compound, and the like) in the

photo mask, the phase shift film in the phase shift mask

blank, and the like.

15   Moreover, the phase shift mask blank of the present

invention is not limited to the halftone phase shift mask

blank. For a purpose of setting the dispersion of the phase

angle within ±2°, the present invention can also be applied

to a blank for manufacturing various types of phase shift

20   masks such as Levenson type, auxiliary pattern type, and

self-matching type (edge emphasizing type).

                 BRIEF DESCRIPTION OF THE DRAWINGS

       FIG. 1 is an explanatory view of the transfer

25   principles used in the manufacture of a halftone phase shift

mask according to the present invention.

       FIG. 2 is a schematic view of a sputtering chamber

in a DC magnetron sputtering apparatus used in an embodiment.

FIG. 3 is a graph showing dispersions of a phase angle and transmittance among blanks in the embodiment.

FIG. 4 is a graph showing dispersions of the phase angle and transmittance among the blanks in another embodiment.

FIG. 5 is a graph showing the relation between DC power and phase angle.

FIG. 6 is a graph showing the relation between film formation time and the phase angle and transmittance.

FIG. 7 is a graph showing the relation between nitrogen flow rate and phase angle.

FIG. 8 is a schematic diagram showing the positional relation between a target and a substrate.

FIG. 9 is a graph showing upper and lower limits of T/S with which a phase angle distribution within ±2° and a transmittance distribution within ±4% can be realized for a given offset distance.

FIG. 10 is a schematic diagram showing a sputtering apparatus of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Examples of the present invention will be described hereinafter in further detail.

The DC magnetron sputtering apparatus described above with reference to FIG. 1 was used to continuously form films of 200 halftone phase shift mask blanks for an ArF

excimer laser (193 nm) one by one at constant intervals.

Concretely, a mixed target (Mo:Si=8:92 mol %) of molybdenum (Mo) and silicon (Si) was used to form a nitrided thin film (film thickness of about 670 angstroms) of

5   molybdenum and silicon (MoSiN) on a transparent substrate by reactive sputtering (DC sputtering) in a mixed gas atmosphere (Ar:N_2 = 10%:90%, pressure: 0.1 Pa) of argon (Ar) and nitrogen (N_2). In this manner, the phase shift mask blank (film composition: Mo:Si:N=7:45:48) for an ArF excimer

10   laser (wavelength of 193 nm) was obtained.

Here, a sputtering chamber 13 in the DC magnetron sputtering apparatus shown in FIG. 1 has a vacuum tank 1 as shown in FIG. 2. A magnetron cathode 2 and substrate holder 3 are disposed in the vacuum tank 1. A sputtering target 5

15   bonded to a backing plate 4 is attached to the magnetron cathode 2. In the example, oxygen-free steel is used in the backing plate 4, and indium is used to bond the sputtering target 5 to the backing plate 4. The backing plate 4 is directly or indirectly cooled by a water cooling mechanism.

20   The magnetron cathode 2, backing plate 4 and sputtering target 5 are electrically connected to one another. A transparent substrate 6 is attached to the substrate holder 3.

Additionally, in a constitution of the apparatus

25   used in the present example, the sputtering target 5 and substrate 6 in FIG. 2 are arranged so that opposite surfaces of the substrate and target form a predetermined angle as

shown in FIG. 8. In this case, the offset distance between the sputtering target and the substrate was set to 340 mm, the vertical distance between the target and the substrate (T/S) was 380 mm, and the target inclination angle was 15°.

5   The vacuum tank 1 is evacuated by a vacuum pump via an exhaust port 7. When the pressure in the vacuum tank reaches a degree of vacuum which does not influence a property of the formed film, a mixed gas containing nitrogen is then introduced via a gas introduction port 8, a DC power 10   supply 9 is used to apply a negative voltage to the magnetron cathode 2, and sputtering is performed. The DC power supply 9 has an arc detecting function, and can monitor an electric discharge state during sputtering. The pressure inside the vacuum tank 1 is measured by a pressure 15   gauge 10.

The transmittance of a light semi-transmission film formed on the transparent substrate is adjusted according to the type and mixture ratio of gases introduced via the gas introduction port 8. When the mixed gas contains argon and 20   nitrogen, the transmittance is increased by increasing the ratio of nitrogen. When a desired transmittance cannot be obtained by adjusting the ratio of nitrogen, oxygen is added to the mixed gas containing nitrogen, and the transmittance can further be increased.

25   The phase angle of the light semi-transmission film was adjusted by a sputtering time, and the phase angle in an exposure wavelength was adjusted to about 180°.

Evaluation of Dispersion among Blanks

Dispersions of the phase angle and transmittance among the blanks formed as described above were checked with respect to 200 phase shift mask blanks (size: 15.2 cm square). Results are shown in FIG. 3.

As seen from FIG. 3, on and after the third blank, halftone phase shift mask blanks whose dispersions of the phase angle and transmittance among the blanks are within ±2° and within ±4%, respectively, can steadily be manufactured. Additionally, it was confirmed also with respect to the 11-th blank to 200-th blank that the dispersions of the phase angle and transmittance among the blanks were within ±2° and within ±4%, respectively. In this case, yield is 100% with respect to the phase angle and transmittance.

Additionally, in Example 2, 200 blanks were prepared similarly as the aforementioned Example 1 except that the sputtering chamber was opened for maintenance midway (at the 190-th blank), and the dispersions of the phase angle and transmittance among the blanks were checked. Results are shown in FIG. 4.

As seen from FIG. 4, with use of the apparatus of the present invention, the halftone phase shift mask blanks whose dispersions of the phase angle and transmittance among the blanks are within ±2° and within ±4%, respectively, can steadily be manufactured, excluding the first several blanks initially produced and the five blanks immediately produced

after opening the sputtering chamber for maintenance. It is
also seen that the yield is 100% with respect to the phase
angle and transmittance.

In a conventional manufacturing apparatus either
about ten substrates were simultaneously introduced into a
load lock chamber or an in-line type manufacturing apparatus
was used to manufacture the halftone phase shift mask blanks.
However, in either apparatus, it was difficult to suppress
the dispersions of the phase angle and transmittance among
the blanks to within ±2° and within ±4%, respectively, and
the yield was bad.

Moreover, in Example 1, the transparent substrate
was rotated during film formation. Furthermore, the
transparent substrate completed an integral number of
rotations between the start and end of the film formation,
while the film formation was performed. The dispersions of
the phase angle and transmittance in a plane were checked.

As a result, it was confirmed that halftone phase
shift mask blanks having dispersions of the phase angle and
transmittance in the plane within ±2° and ±4%, respectively,
can steadily be manufactured.

Furthermore, the following was seen in the
aforementioned examples.

As shown in FIG. 5, in order to suppress the
dispersion of the phase angle to a range of about 180° to
about 172°, it is necessary to maintain the power·of the DC
power supply in a range of about 1.77 kW to about 1.825 kW

(preferably in a range of about 1.82 kW to 1.81 kW in order
to suppress the dispersion of the phase angle to a range of
about 180° to about 178°). Therefore, it is necessary to
suppress a fluctuation of the power of the DC power supply
5   from a center value to ±0.5%.

       Similarly, as seen from FIG. 6, in order to suppress
the dispersions of the phase angle and transmittance, it is
necessary to maintain the film formation time in a range of
about 560 seconds to about 615 seconds (preferably about 600
10   seconds to about 594 seconds in order to suppress the
dispersion of the phase angle to a range of about 180° to
about 178°). Therefore, it is necessary to suppress a
fluctuation of the film formation time from a center value to
±0.5%.

15   Similarly, as seen from FIG. 7, in order to suppress
the dispersion of the phase angle, the flow rate of nitrogen
introduced during sputtering is adjusted so that the content
of nitrogen measured by ESCA in a nitrided metal silicide
film is larger than the content of silicon, and the
20   influence of a fluctuation of nitrogen partial pressure on
an optical property is reduced. For this purpose, it is
necessary to maintain the flow rate of nitrogen in a range
of about 35 sccm or more (preferably about 35 sccm to about
35.5 sccm in order to suppress the dispersion of the phase
25   angle to a range of about 180° to about 178°). Additionally,
the nitrogen flow rate at which the influence of the
fluctuation of nitrogen partial pressure on the optical

property can be reduced changes with an exhaust property and
DC power of the apparatus.

Evaluation of Dispersion in Plane

The dispersions of the phase angle and transmittance
in a plane were checked with respect to one of the phase
shift mask blanks obtained as described above.

As a result, the dispersion of the phase angle was
within ±0.8% (average value of 179.5°, range of 178.8° to
180.3°) in a range of 132 mm square excluding a substrate
peripheral portion of 10 mm. Moreover, the dispersion of
the transmittance was within ±1.3% (average value of 6.16%,
range of 6.08% to 6.23%).

Additionally, for comparison, when the film
formation was performed at an offset distance of 340 mm, a
vertical distance between the target and the substrate (T/S)
of 400 mm, and a target inclination angle of 15°, the
dispersion of the phase angle was ±3.5° (average value of
178.8°, range of 175.3° to 181.7°). Moreover, the dispersion
of the transmittance was ±8% (average value of 6.07%, range
of 5.83% to 6.56%).

Furthermore, for comparison, when the target was
disposed opposite to the substrate (offset distance of 0 mm,
and target inclination angle of 0°), the dispersion of the
phase angle was ±2.7° (average value of 179.8°, range of
177.1° to 182.0°) for a target with a diameter of 16 inches.
Moreover, the dispersion of the transmittance was ±4.2%
(average value of 6.19%, range of 6.00% to 6.45%).

With a larger offset distance, it is easier to reduce the dispersion in the plane. However, when the offset distance is excessively large, the capacity of the vacuum tank increases, evacuation or depressurization is therefore deteriorated, and film formation speed is lowered.

Additionally, the dispersion in the plane was evaluated by judging whether or not both a maximum point (plus value) and minimum point (minus value) with respect to the average value (center value) were within a defined range.

The preferred examples of the present invention have been described above, but the present invention is not limited to the aforementioned examples.

For example, molybdenum was used as a metal constituting the light semi-transmission film, but this is not required, and zirconium, titanium, vanadium, niobium, tantalum, tungsten, nickel, palladium, and the like can be used.

Moreover, a target of molybdenum and silicon was used as the target containing metal and silicon, but this is not limiting. In a target containing metal and silicon, molybdenum is particularly superior among the aforementioned metals in controlling the transmittance and, further, because target density increases and particles in the film can be reduced through the use of a sputtering target containing metal and silicon. Titanium, vanadium, and niobium are superior in resistance to an alkaline solution, but slightly inferior to molybdenum in the target density.

Tantalum is superior in its resistance to the alkaline solution and target density, but slightly inferior to molybdenum in controlling transmittance. Tungsten has properties similar to those of molybdenum, but is slightly inferior to molybdenum in an electric discharge property during sputtering. Nickel and palladium are superior in the optical property and resistance to the alkaline solution, but dry etching is slightly difficult to perform. Zirconium is superior in its resistance to the alkaline solution, but inferior to molybdenum in the target density, and the dry etching is slightly difficult to perform. Considering these, molybdenum is most preferable at present. Molybdenum is also preferable for a nitrided molybdenum and silicon (MoSiN) thin film (light semi-transmission film), with its superior chemicals resistance such as acid resistance and alkali resistance.

Moreover, in order to obtain the thin film of a composition in which electric discharge stability is secured during film formation and various properties of the phase shift mask are satisfied, the target containing 70 to 95 mol % of silicon, and the metal is preferably subjected to DC magnetron sputtering in an atmosphere containing nitrogen. Thereby, a light semi-transmission film containing nitrogen, metal and silicon is preferably formed.

When the content of silicon in the target is larger than 95 mol %, a voltage is not easily applied (electricity is not easily passed) to a target surface (erosion portion)

in the DC sputtering, and the electric discharge becomes unstable. Moreover, when the content of silicon is less than 70 mol %, a film constituting a light semi-transmission portion with a high transmittance cannot be

5 obtained. Furthermore, electric discharge stability is further enhanced by combination of the nitrogen gas with the DC sputtering.

Additionally, the electric discharge stability during film formation also influences film quality. When the

10 electric discharge stability is superior, a light semi-transmission film with a satisfactory film quality is obtained.

As described above, according to the present invention, there can be provided the manufacturing method of

15 the phase shift mask blank in which the dispersions of phase angle and transmittance among blanks can be reduced as much as possible and the yield is satisfactory.

Moreover, there can be provided the manufacturing method of a phase shift mask blank in which the dispersions

20 of phase angle and transmittance in the plane of the blanks can be reduced as much as possible and the yield is satisfactory.

Furthermore, there can be provided the manufacturing apparatus for a phase shift mask blank in which the

25 dispersions of phase angle and transmittance among the blanks can be reduced as much as possible and which can be manufactured with a satisfactory yield.

Additionally, there can be provided the manufacturing apparatus for a phase shift mask blank in which the dispersions of phase angle and transmittance in the plane of the blanks can be reduced as much as possible and which can be manufactured with a satisfactory yield.